USER PRIORITY MAPPING IN BRIDGED VLANS

Technical Field

[0001] The invention relates to data communication networks which include bridges or similar data handling devices. The invention relates particularly to bridges and methods performed in bridges for maintaining differential treatment of data frames having different priorities in a virtual LAN (VLAN). Data may be carried between segments of the VLAN by connections in a connection-based network such as an asynchronous transfer mode (ATM) network or a multi-protocol label switching ("MPLS") network.

Background

[0002] In this disclosure the term virtual LAN ("VLAN") means a data communication network which comprises a number of segments which are connected together by links which operate according to a networking protocol different from that of the network segments. For example, two segments of an ethernet network may be connected by way of a channel in a connection-based network. The channel may be, for example, a virtual circuit in an asynchronous transfer mode (ATM) network. Each of the network segments may be interfaced to the connection-based network by a bridge.

[0003] Data may be delivered between the segments in any of a wide number of ways. For example, where the segments comprise ethernet segments and the network which connects the segments comprises an ATM network then ethernet frames may be carried between the segments according to standards such as local area network

emulation ("LANE"), multi-protocol over ATM ("MPOA") or IP over ATM. Data may be carried on a path in a MPLS network. The particular format by which data is conveyed between network segments is not important to this invention.

[0004] IEEE standard 802.1Q provides a set of capabilities which permit media access control (MAC) bridges to define and manage networks in which multiple broadcast domains can co-exist on a single physical medium. This IEEE standard uses the term "VLAN" to describe such networks. In this disclosure the term VLAN is not used in the same sense as it is in IEEE 802.1Q (although this invention may be applied to networks which operate, or which include portions which operate, according to IEEE 802.1Q). IEEE standard 802.1D describes the operation of MAC bridges.

[0005] Various networking protocols permit priorities (sometimes called "user priorities") to be assigned to data. Through the use of such protocols, data having different priority levels can be treated differently. For example, certain levels of Quality of Service (QoS) may be specified for each priority level. An example of a networking protocol which accommodates user priorities is the IEEE 802.1D standard which relates to ethernet networks. Annex H of IEEE standard 802.1D describes a way to map user priorities to service queues.

[0006] U.S. patent No. 6,175,569 discloses a method for extending QoS guarantees to stations on a token ring LAN. The method involves a LAN station originating a request for a connection through an ATM network to either a remote ATM station or a remote LAN station. A LAN

/ ATM interface device receives the request and attempts to establish the requested connection.

[0007] U.S. patent No. 5,978,378 discloses a method for identifying frames which relate to a VLAN and excluding such frames from ports not associated with the VLAN.

[0008] There is a need for ways to accommodate user priorities in VLANs.

Summary of the Invention

[0009] The invention relates to methods and apparatus for handling data frames having different priorities in bridges and bridged VLANS. One aspect of the invention provides apparatus for handling data frames which are each associated with one of a plurality of priorities. The apparatus comprises: a bridge having a plurality of bridge ports, a first one of the bridge ports having a plurality of service interfaces, each of the service interfaces capable of being associated with a channel in a connection-based network; a map associated with the first one of the bridge ports, the map providing a correspondence between each of the plurality of priorities and one of the service interfaces; and a forwarding system configured to read a priority of a data frame to be forwarded onto the connection-based network by way of the first one of the ports, identify a service interface which the map indicates corresponds to the read user priority and forward the data frame over a channel in the connection-based network associated with the identified service interface.

[0010] In some embodiments, each of the service interfaces is associated with a channel identified by a predetermined connection identifier. The connection-based network may comprise an ATM network in which channels are each identified by a connection identifier comprising a VPI and a VCI. Each of the service interfaces associated with the first one of the bridge ports may be associated with a channel having the same predetermined VPI.

[0011] Another aspect of the invention provides a bridge for connecting a segment of a LAN to a connection-based network. The bridge comprises: a plurality of bridge ports; means for reading priorities of data frames directed by the bridge to at least a first one of the bridge ports; a plurality of service interfaces associated with the first one of the bridge ports, each of the service interfaces capable of being associated with a channel in a connection-based network; means for determining a number of the service interfaces associated with active connections in the connection-based network; means for establishing a mapping between user priorities read by the means for reading priorities of data frames and the service interfaces associated with active connections in the connection-based network based at least in part on a number of the service interfaces associated with active connections in the connection-based network; and, means for assigning frames to the service interfaces based upon the user priorities and the mapping.

[0012] A still further aspect of the invention provides a method for directing frames between segments of a VLAN over a connection-based network. The method comprises: receiving at a first bridge port

connected to a first segment of a VLAN a frame addressed to a node on a second segment of the VLAN; forwarding the frame to a second bridge port associated with a second segment of the VLAN and determining a user priority of the frame; and, based on the user priority, assigning the frame to one of a plurality of service interfaces associated with the second bridge port, each of the service interfaces capable of delivering data to the second segment of the VLAN by way of a corresponding channel in a connection-based network.

[0013] Further aspects of the invention and features of specific embodiments of the invention are described below.

Brief Description of the Drawings

[0014] In drawings which illustrate non-limiting embodiments of the invention,

Figure 1 is a schematic diagram of a network having a number of ethernet segments connected by channels in a connection-based network;

Figure 2 is a block diagram of a bridge which according to one embodiment of the invention;

Figure 3 illustrates a pair of segments of a VLAN interconnected by a plurality of channels through a connection-based network;

Figure 4 is a diagram illustrating a set of service interfaces which receives data frames, which each may be associated with one of a number of different user priorities, and forwards the data frames by way of a number of active channels according to a currently active mapping between user priorities and channels;

Figures 5A through 5H illustrate a scheme comprising a plurality of mappings between user priorities and channels for different numbers of available channels;

Figure 5I shows an example of one way to remap user priorities to channels upon failure of a channel; and,

Figure 6 is a flow chart which illustrates a method for forwarding data frames according to one embodiment of the invention.

Description

[0015] Throughout the following description, specific details are set forth in order to provide a more thorough understanding of the invention. However, the invention may be practiced without these particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the invention. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

[0016] Figure 1 illustrates a simple network **10**. Network **10** comprises three ethernet segments **12A, 12B** and **12C**. Ethernet segments **12A**, **12B**, and **12C** are interconnected by a connection-based network **14**. Connection-based network **14** may comprise, for example, an ATM network or an MPLS network. Bridges **16A, 16B** and **16C** (collectively bridges **16**) respectively provide interfaces between ethernet segments **12A**, **12B** and **12C** and connection-based network **14**. Connection-based network **14** provides channels (which may be virtual circuits) capable of carrying data between bridges **16**. The virtual circuits may comprise, for example, switched virtual circuits ("SVCs"), soft

permanent virtual circuit connections ("SPVCs"), permanent virtual circuit connections ("PVCs") or other channels capable of carrying data between bridges **16**.

[0017] As shown in Figure 2, in one embodiment of the invention, each bridge **16** comprises an ethernet card **20** which connects to a cell relay card **22** by way of a device fabric **24**. Cell relay card **22** provides an interface to connection-based network **14**. Device fabric **24** extends channels of connection-based network **14** to ethernet card **20.** Ethernet card **20** provides a local interface **23** to a LAN segment.

[0018] A bridging system **27** is on ethernet card **20**. Bridging system **27** comprises a plurality of bridge ports by way of which data can be sent and/or received. For convenience of description, bridge ports which send data to and receive data from a local interface **23** connected to a local network segment are indicated by the reference numeral **25** while bridge ports which send and receive data by way of device fabric **24** are indicated by the reference numeral **26**. Each of the bridge ports may be associated with a number of services. The services may, for example, dispatch data to different destinations by way of connections in connection-based network **14**, maintain data in priority queues in connected ethernet networks, dispatch ethernet data frames or the like.

[0019] In the illustrated embodiment, bridge **16** includes a filtering system **28** which includes a filtering database **28A**. Filtering database **28A** keeps records which associate known destinations with the bridge ports by way of which data can be sent to those known destinations.

Filtering system **28** drops packets which are addressed to destinations located on the same port at which the packets are received. When filtering system **28** receives at a bridge port a packet addressed to a destination known to be associated with another bridge port then filtering system **28** forwards the packet to the other bridge port. When filtering system **28** receives at a bridge port a packet destined for a destination not known to filtering database **28A** then filtering system **28** may send the packet to all other bridge ports so that the packet can reach its destination if it is on a segment **12** which can be reached from bridge **16**. The construction and use of filtering systems and filtering databases in network bridges is well known to those skilled in the art and is therefore not described herein in detail.

[0020] Bridge **16** receives packets from a connected LAN segment **12** at local interface **23** which is connected to a first bridge port **25**. Bridge **16** may comprise additional bridge ports connected to additional local interfaces (not shown) which are associated with different LAN segments. Bridge **16** also passes data received from other sources (such as other LAN segments) to LAN segment **12** by way of bridge port **25**. Bridge port **25** may implement a set of service queues which handle the forwarding of packets having different user priorities onto LAN segment **12**. The service queues may be implemented, for example, according to the IEEE 802.1D and 802.1Q specifications.

[0021] Bridging system **27** has one or more bridge ports **26** which can each be used to send and receive data by way of connection-based network **14**. In the embodiment illustrated in Figure 2 there are three

such bridge ports **26A**, **26B** and **26C**. Each of these bridge ports **26** is associated with a plurality of service interfaces **30**. Each of service interfaces **30** may be associated with a channel through cell relay network **14**.

[0022] For example, where connection-based network **14** comprises an ATM network then each of bridge ports **26A**, **26B** and **26C** may be associated with one or more virtual circuits through ATM network **14**. Each channel is identified by a connection identifier. The connection identifier may comprise a pair of a virtual path identifier ("VPI") and a virtual channel identifier ("VCI").

[0023] In specific embodiments of the invention, each of service interfaces **30** is associated with a specific connection identifier that identifies a connection in fabric **24** (which may be considered to be an extension of ATM network **14**). In some implementations of the invention the connections in device fabric **24** are identified by VPI/VCI pairs and each bridge port **26** is associated with a predetermined VPI. Different service interfaces **30** associated with each of bridge ports **26** (in this example, each service interface **30** provides a connection to a virtual circuit in ATM network **14**) may be made to correspond with a different VCI. Each of service interfaces **30** thereby has a predetermined association with a specific channel in device fabric **24** which is identified by the VPI/VCI pair obtained from the VPI associated with the port **26** with which the service interface **30** is associated and the VCI associated with the service interface **30**.

[0024] In typical applications the set of channels available to each bridge port **26** extend to a common destination. In this example, each of the channels extend to a corresponding bridge port **26** on another one of bridges **16**. At a given time each of bridge ports **26A**, **26B**, and **26C** may have access to a number (zero, one, or more) of available channels in connection-based network **14** by way of the service interfaces **30** which are associated with that bridge port **26**. In general, the number of channels available to each bridge port **26** may be different. The number of available channels may vary. From time-to-time an additional channel may be made available to a bridge port **26** or some channels may become unavailable due to reassignment of resources in connection-based network **14**. Some channels may also become unavailable due to failures of connections in connection-based network **14**.

[0025] Figure 3 illustrates a portion of a VLAN **10** in which two bridges **16** are interconnected by a plurality (8 in this example) of channels **15** through a connection-based network **14**. 6 of the channels are available for carrying data. Two of the channels **15** which are drawn in dashed lines are unavailable. Where there are a plurality of available channels **15** connecting segments **12A** and **12B** then each of the available channels may be assigned to carry data of different priorities.

[0026] Data packets on each LAN segment **12** may be associated with a user priority. For example, VLAN-tagged and priority-tagged ethernet frames have a header which includes a three-bit user-priority field. The user priority field can hold values in the range of 0 to 7. Typically a user-priority value of 0 indicates that no priority has been

assigned to the frame. User priority values in the range of 1 to 7 indicate different priority levels with 7 indicating highest priority and 1 indicating lowest priority. The user priorities may be assigned, for example in accordance with Appendix H of IEEE specification 802.1D. Other schemes for assigning user priorities to data frames could also be used.

[0027] Bridging system **27** maintains a mapping between user priorities and available channels **15** in cell relay network **14**. In preferred embodiments, for each of bridge ports **26**, a map is maintained. The map may comprise, for example, a lookup table accessible to the system which manages the port **26**. The map associates each of the user priorities in whatever system of user priorities is being used with a channel **15** in connection-based network **14** which is accessible by way of one of the service interfaces **30** associated with the port **26**. The map may map between user priorities and predetermined connection identifiers for the channels. For example, bridging system **27** may contain data which associates each of bridge ports **26** with a VPI and data which associates each of service interfaces **30** with a VCI, as described above. Equivalently, the map may map between user priorities and service interfaces **30**.

[0028] Providing a predetermined mapping between bridge ports **26** and channel identifiers (such as VPIs) can permit channels in the connection-based network to be extended seamlessly to bridge ports **26**.

[0029] Different channels **15** in cell relay network **14** may be configured to provide different desired levels of QoS. For example, low-

priority frames could be sent over a channel **15** comprising an unspecified bit rate (UBR) virtual circuit. Higher priority frames could be sent over a channel **15** comprising a variable bit rate (VBR) virtual circuit. By assigning different ATM traffic parameters to the virtual circuits, multiple classes of LAN transport are established. Different channels **15** could take different routes through cell relay network **14**.

[0030] In preferred embodiments, for each bridge port **26** there is at most one channel **15** in cell relay network **14** for each user priority. Within each bridge port **26**, one or more user priorities may be mapped to each service interface **30**. This ensures that the order in which frames are received on the same bridge port **26** will be preserved within any user priority class and is compatible with the requirements of the Spanning Tree Protocol for network configuration. All channels **15** which originate at a bridge port **26** preferably terminate at the same location (for example, a bridge port **26** in another bridging system **27**).

[0031] Figure 6 illustrates a method **100** according to the invention for forwarding a priority tagged data frame. A frame is received at block **102**. In blocks **104** and **106** the priority of the frame is determined and the frame is forwarded to a bridge port for delivery to a destination. Blocks **104** and **106** may occur in either order. In block **108**, the frame is assigned to a channel (or equivalently to a service interface associated with an available channel). Assigning the frame to a channel may comprise looking up the priority determined in block **104** in a map. Then in block **110** the frame is forwarded on the channel.

[0032] The mapping used by bridging system **27** for a bridge port **26** will depend upon the number of channels **15** available to the bridge port **26** (e.g. to a number of the service interfaces **30** which are connected to active channels in network **14**). Since the number of available connections **15** may vary over time, a scheme comprising a plurality of mappings may be provided. As the number of available channels **15** changes, different mappings are selected from the scheme. For example, where, for a particular bridge port **26** there is only a single channel **15** available, the mapping is trivial. All data which passes through that bridge port **26** must travel on the single available channel. As more channels **15** become available, the correspondence between user priorities and channels **15** can be remapped so that frames having different user-priorities can be sent over different channels **15**. The mapping may be stored in a lookup table, the lookup table may be updated each time a channel is added or dropped.

[0033] Bridging system **27** may track the channels available at service interfaces **30** of a port **26** in various ways including receiving and processing connect requests from a system which manages network **14** (or a part thereof) or receiving information regarding channels via signalling in network **14**.

[0034] Preferably, the scheme of mappings used by bridging system **27** is such that when a channel **15** is added, only frames having priorities which will be carried on the newly added channel need to be remapped. Table I illustrates an example scheme for mapping frames with different user-priorities to different numbers of channels (numbered from 1 to 8).

Figures 5A through 5H illustrate the mappings which may be provided for 1 to 8 available channels. In Table I, the channels are numbered from 1 to 8, with number 1 being assigned to the first available channel number 2 to the next available channel, and so on.

[0035] The scheme of Table I minimizes priority remapping when channels are added or removed. It can bee seen, for example, that when a third channel becomes available only those frames having user priorities 6 and 7 are remapped according to the scheme of mappings of Table I. Other equivalent schemes in which only those priorities carried by a channel which is added or removed require remapping also provide this benefit.

TABLE I - ASSIGNMENTS OF PRIORITIES TO CHANNELS FOR DIFFERENT NUMBERS OF CHANNELS

Number of channels	1	2	3	4	5	6	7	8
Priority	Connection Used for Priority							
0	1	1	1	1	1	1	1	1
1	1	1	1	4	4	4	4	4
2	1	1	1	4	4	4	4	8
3	1	1	1	1	1	6	6	6
4	1	2	2	2	2	2	2	2
5	1	2	2	2	5	5	5	5
6	1	2	3	3	3	3	3	3
7	1	2	3	3	3	3	7	7

[0036] Preferably channels 1 through 8 are made available in order (unless one or more channels has failed). Where channels are made available in order, a higher-numbered channel cannot be established until all lower-numbered channels have been established.

[0037] If data which is untagged (i.e. does not include an explicit user priority) arrives at a bridge **16** on a channel, then bridge**16** can use the mapping between channels (or service interfaces) and user priorities and information identifying the channel (or service interface) on which the data arrived to assign a priority to the data and to tag the data with the assigned priority. If more than one user priority is assigned to the same channel then the bridge **16** may assign a priority to data which arrives on that channel according to a rule. For example, the bridge **16** may assign to the data the lowest priority currently mapped to the channel on which the data was received.

[0038] Preferably, the channels to which the ports of bridging system **27** are associated are either all endpoints of point to point (P2P) connections, leaf endpoints of point to multi point (P2MP) connections or root endpoints of P2MP connections. All of the channels preferably terminate at the same device. This simplifies configuration.

[0039] Bridges **16** may permit support for user priorities to be disabled. Where support for user priorities is disabled, all VLAN traffic may be carried across connection-based network **14** over a single channel per port.

[0040] In cases where the connection identifier (such as a VPI/VCI value) corresponding to each service interface **30** of bridging system **27** is predetermined, a channel may be set up through connection-based network **14** to a specific service interface **30** of bridging system **27** using signalling. Where cell relay network **14** comprises an ATM network, the channels in network **14** may be provided by soft permanent virtual circuits (SPVCs) which connect to service interfaces **30**. If a SPVC needs to be rerouted then it can reconnect to a service interface **30** without reconfiguration because the service interface **30** has a predetermined VPI/VCI assignment.

[0041] Bridges **16** are preferably configured to accommodate the possibility that one or more channels may fail. Bridge **16** may receive a signal indicating that a channel has failed. The message may be generated by any suitable failure detection mechanism. One such mechanism is described, for example, in the commonly owned and co-pending application entitled METHOD AND APPARATUS FOR CHECKING CONTINUITY OF LEAF-TO-ROOT VLAN CONNECTIONS which is hereby incorporated by reference herein. Upon the failure of a channel (or upon the failure of a channel out of order) bridge **16** may react in various ways including:

- bumping data having each of the user priorities which had been assigned to the failed channel to the channel handling the next lower user priority;
- bumping the user priority (or priorities)which had been assigned to the failed channel to the channel handling the lowest priority frames for which a channel remains available; and,

- dropping frames having the user priority (or priorities) associated with the failed channel.

Where ***N*** channels are provided and one of the channels fails then bridge **16** could also react by remapping the associations between user priorities and the available channels according to Table I for the case where there are ***N***-1 channel (with the channels renumbered to exclude the failed channel). Depending upon the value of ***N*** and which channel it is that failed, this could result in the need to reroute frames in addition to those which would otherwise have been carried on the failed channel. Preferably the manner in which bridging system **27** reacts to failure of a channel is configurable.

[0042] Figure 5I illustrates a situation which may exist after failure of the channel labelled 3. Frames associated with the user priority "6" which had previously been carried on channel 3 are rerouted to be carried on channel 5 (which was previously carrying only frames of user priority 5). This is an example of bumping each of the user priorities which had been assigned to the failed channel to the channel handling the next lower user priority.

[0043] As noted above, in some embodiments of the invention, bridging system **27** is on a card located **20** in a bridge **16** and the final part of each channel **15** extends through a device fabric **24** which is internal to the bridge **16**. In such cases the VPI/VCI or other connection identifier assigned to channels terminating at service interfaces **30** of bridging system **27** may be internal to the bridge **16**.

[0044] Those skilled in the art will appreciate from the foregoing that it is possible to implement this invention in ways which provide a predetermined mapping between user priorities channels. More priorities may be supported automatically as more channels become available to carry data. In preferred embodiments of the invention it is not necessary to reroute all data traffic as channels are added and dropped. Upon failure of a channel traffic may be automatically routed to a lower priority.

[0045] Certain implementations of the invention comprise computer processors which execute software instructions which cause the processors to perform a method of the invention. For example, bridging system **27** may comprise a computer processor which executes software instructions which cause the processor to associate specific ones of ports **30** with specific channels on cell relay network **14**. The invention may also be provided in the form of a program product. The program product may comprise any medium which carries a set of computer-readable signals comprising instructions which, when executed by a computer processor, cause the data processor to execute a method of the invention. The program product may be in any of a wide variety of forms. The program product may comprise, for example, physical media such as magnetic data storage media including floppy diskettes, hard disk drives, optical data storage media including CD ROMs, DVDs, electronic data storage media including ROMs, flash RAM, or the like or transmission-type media such as digital or analog communication links.

[0046] Where a component (e.g. a software module, processor, assembly, device, circuit, etc.) is referred to above, unless otherwise indicated, reference to that component (including a reference to a "means") should be interpreted as including as equivalents of that component any component which performs the function of the described component (i.e., that is functionally equivalent), including components which are not structurally equivalent to the disclosed structure which performs the function in the illustrated exemplary embodiments of the invention.

[0047] As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. For example, maps are described above as comprising lookup tables. Maps may also comprise other hardware, software, or hardware-software combinations which are capable of maintaining a correspondence between user priorities and service interfaces **30** (or, equivalently, available ones of channels **15**). The invention has application to devices other than bridges. For example, the invention could be applied to devices such as ethernet LAN services units ("ELSUs") which simply present all ethernet traffic to connected channels such as ATM virtual channels, and receive traffic from the connected channels but do not necessarily provide other functions often provided by bridges. Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.